

## **Ionospheric Monitoring and Specification Utilizing Data from the Defense Meteorological Satellite Program**

**W. R. Coley  
R. A. Power  
P. C. Anderson**

**University of Texas at Dallas  
800 Campbell Road, MS/WT15  
Richardson, TX 75080**

**Scientific Report No. 2**

**20 October 2008**

**Approved for Public Release; Distribution Unlimited**



**AIR FORCE RESEARCH LABORATORY  
Space Vehicles Directorate  
29 Randolph Rd  
AIR FORCE MATERIEL COMMAND  
HANSCOM AFB, MA 01731-3010**

---

AFRL-RV-HA-TR-2008-1164

Using Government drawings, specifications, or other data included in this document for any purpose other than Government procurement does not in any way obligate the U.S. Government. The fact that the Government formulated or supplied the drawings, specifications, or other data, does not license the holder or any other person or corporation; or convey any rights or permission to manufacture, use, or sell any patented invention that may relate to them.

This report is published in the interest of scientific and technical information exchange and its publication does not constitute the Government's approval or disapproval of its ideas or findings.

This technical report has been reviewed and is approved for publication.

/ signed /

Alan D. Rebello  
Contract Manager

/ signed /

Dwight T. Decker, Chief  
Space Weather Center of Excellence

Qualified requestors may obtain additional copies from the Defense Technical Information Center (DTIC). All other requests shall be referred to the National Technical Information Service.

If your address has changed, if you wish to be removed from the mailing list, or if the addressee is no longer employed by your organization, please notify AFRL/RVIM, 29 Randolph Rd., Hanscom AFB, MA 01731-3010. This will assist us in maintaining a current mailing list.

Do not return copies of this report unless contractual obligations or notices on a specific document require that it be returned. For Unclassified, limited documents, destroy by any means that will prevent disclosure of the contents or reconstruction of the document.

REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
<small>Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.</small>					
1. REPORT DATE (DD-MM-YYYY) 20-10-2008		2. REPORT TYPE Scientific, Interim		3. DATES COVERED (From - To) October 2007-September 2008	
4. TITLE AND SUBTITLE Ionospheric Monitoring and Specification Utilizing Data from the Defense Meteorological Satellite Program				5a. CONTRACT NUMBER FA8718-06-C-0070	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER 62601F	
				5d. PROJECT NUMBER 1010	
6. AUTHOR(S) W. R. Coley R. A. Power P. C. Anderson				5e. TASK NUMBER SD	
				5f. WORK UNIT NUMBER A1	
				8. PERFORMING ORGANIZATION REPORT NUMBER  632019	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)  University of Texas at Dallas 800 Campbell Road MS/WT15 Richardson, TX 75080				10. SPONSOR/MONITOR'S ACRONYM(S) AFRL/RVBXS	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Air Force Research Laboratory 29 Randolph Road Hanscom AFB, MA 01731-3010				11. SPONSOR/MONITOR'S REPORT NUMBER(S) AFRL-RV-HA-TR-2008-1164	
12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited.					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT <p>Following the November 2006 launch of the Defense Meteorological Satellite Program (DMSP) F17 spacecraft, work was begun at the University of Texas at Dallas on the development of ground software for the routine production of geophysical data records from the F17 SSIES-3 instrument package data that is provided to UTD by AFRL. The SSIES-3 sensors include the Retarding Potential Analyzer, (RPA), the Drift Meter (DM), the Scintillation Meter (SM), the Electron Sensor (ES), and the Plasma Plate (PP).</p> <p>The primary accomplishment this year was the refinement of the integrated software package used to routinely convert the raw data to time-tagged geophysical parameters. A basic production level software package has been created that processes the RPA, DM, SM, and ES sensor data. The current version of this software was delivered to AFRL for implementation there. An investigation of problems with density measurements produced by the Plasma Plate has led to that sensor being disabled until ionospheric conditions change. While the RPA algorithm is functioning well, it is expected, based on past experience, that as larger volumes of data are processed further refinement will be required.</p>					
15. SUBJECT TERMS IGRF, Corrected geomagnetic coordinates, South Atlantic Anomaly, Spherical harmonic coefficients					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT  U	18. NUMBER OF PAGES  11	19a. NAME OF RESPONSIBLE PERSON Alan Rebello
a. REPORT U	b. ABSTRACT U	c. THIS PAGE U			19b. TELEPHONE NUMBER (include area code) (781) 377-9669

## **ABSTRACT**

Following the November 2006 launch of the Defense Meteorological Satellite Program (DMSP) F17 spacecraft, work was begun at the University of Texas at Dallas on the development of ground software for the routine production of geophysical data records from the F17 SSIES-3 instrument package data that is provided to UTD by the scientists at the Air Force Research Laboratory (AFRL). The SSIES-3 sensors include the Retarding Potential Analyzer (RPA), the Drift Meter (DM), the Scintillation Meter (SM), the Electron Sensor (ES), and the Plasma Plate (PP).

The primary accomplishment this year was the refinement of the integrated software package used to routinely convert the raw data to time-tagged geophysical parameters. A basic production level software package has been created that processes the RPA, DM, SM, and ES sensor data. The current version of this software was delivered to AFRL for implementation there. An investigation of problems with density measurements produced by the Plasma Plate has led to that sensor being disabled until ionospheric conditions change. While the RPA algorithm is functioning well, it is expected, based on past experience, that as larger volumes of data are processed further refinement will be required.

## CONTENTS

ABSTRACT.....	iii
FIGURES.....	v
1. INTRODUCTION.....	1
2. REMEDIATION OF SINGLE EVENT UPSETS.....	1
3. SSSIES-3 PROCESSING SOFTWARE.....	1
4. MISCELLANEOUS TASKS PERFORMED.....	4
5. WORK PLANNED FOR THE NEXT PERIOD.....	4
6. SCIENTISTS AND ENGINEERS CONTRIBUTING TO THIS RESEARCH.....	5

## FIGURES

Figure 1. Plasma Parameters measured by DMSP F17



## **SSIES-3 Post-Launch Data Analysis Report**

### **1. INTRODUCTION**

Following the November 2006 launch of the Defense Meteorological Satellite Program (DMSP) F17 spacecraft, work was begun at the University of Texas at Dallas on the development of ground software for the routine production of geophysical data records from the F17 SSIES-3 instrument package data that is provided to UTD by the scientists at the Air Force Research Laboratory (AFRL). The SSIES-3 sensors include the Retarding Potential Analyzer (RPA), the Drift Meter (DM), the Scintillation Meter (SM), the Electron Sensor (ES), and the Plasma Plate (PP). Taken together these sensors provide extensive data on the state of the ambient thermal plasma. In addition, UTD has provided support to AFRL as needed for the interpretation and maintenance of these instruments. A brief description of each of the major tasks performed during this contract period follows.

### **2. REMEDIATION OF SINGLE EVENT UPSETS**

After the launch of F17 work was begun on the initial operations support for this spacecraft. The first task was the identification and remediation of single-event upsets occurring in the South Atlantic anomaly region. As was the case for F16, the main electronics package on F17 is apparently susceptible to single event upsets induced by high-energy particle impacts, generally occurring in regions where such particles are often present. A command "reset" re-enables the sensor functions, and the ground command sequences have been reprogrammed to execute the "reset" command during the equatorial crossings of each orbit. While there may be brief data outages after a single-event upset, this command-level fix automatically restores instrument functionality. Evaluation of this fix has been on-going throughout the year and to-date it has proven to be functionally adequate.

### **3. SSIES-3 PROCESSING SOFTWARE**

Work continued in this period on the refinement of the ground software designed to routinely process the raw F17 data from all the sensor heads and produce files of geophysical data records. As part of this effort we are inspecting and evaluating the geophysical data produced by the on-board processing algorithms and comparing these results to those produced by the ground software.

On-going examination of cross-track drifts from the drift meter (DM) and ion densities from the SM is necessary to check the status and performance of these instruments. When  $\text{He}^+$  or  $\text{H}^+$  ions represent a significant fraction of the total ambient ion density, the instrument performance is degraded. The fraction of light ions that constitutes enough to degrade the performance of the instrument depends on the spacecraft and the ionospheric conditions, but is around 5%. A retarding grid in front of the DM aperture, called the DREP, is set at +2 V on all of the operational spacecraft.  $\text{H}^+$  has an energy of 0.3 eV at the spacecraft velocity of 7.5 km/s while  $\text{O}^+$  has an energy of 4.8 eV so most of the light

ions are repelled while the  $O^+$  ions are allowed through. Even so, during the conditions of extremely low solar activity prevailing during this past year the DMSP spacecraft routinely encounters ionospheric conditions of almost pure  $H^+$ . Under these conditions accurate determination of cross-track velocities from the DM is difficult or impossible. This situation is expected to improve in the coming year as levels of solar activity increase and the  $O^+$  concentration increases at DMSP altitudes.

A major part of the software effort concentrated on the refinement of the algorithms for the analysis of data from the retarding potential analyzer (RPA). The RPA software first constructs current-voltage curves (engineering units) from the raw data. Geophysical units are then produced from the RPA by fitting these current-voltage curves to a theoretical function through the use of a least-squares fitting algorithm (Levenberg-Marquardt). The results of an initial evaluation using a simple set of fixed initial conditions indicates that the Levenberg-Marquardt algorithm was converging under a wider variety of environmental conditions for data from the SSIES-3 RPA than was the case for the corresponding SSIES-2 instruments. In particular, it appears that the non-uniform distribution of retarding voltages chosen for use on the SSIES-3 RPA has allowed improved determination of the light ion ( $H^+$  and  $He^+$ ) concentrations over an increased range of ambient ion density. This increased capability has proven valuable over this contract period due to the increased incidence of ionospheric regions of high  $H^+$  concentration encountered by F16 and F17. This was due to an unusually low level of solar activity that led to reduced ionospheric heating. This has in turn led to a low  $H^+/O^+$  transition height meaning that the DMSP spacecraft were operating more routinely in an  $H^+$  rich environment. The improved convergence of the RPA fitting algorithm gives us more confidence in the accuracy of the calculated geophysical parameters. These RPA measured geophysical parameters include total ion density, ion temperature, sensor potential with respect to the ambient plasma, ram component of ion velocity, and ion composition.

The preliminary output feedback algorithm to identify and correct cases where the initial analysis has not functioned correctly has been improved and refined. The output feedback algorithm was improved to identify and correct cases where the initial analysis did not functioned correctly. Evaluation of the results of the least-squares fitting algorithm has continued through processing and examination of multiple orbits of raw data. Software that was written toward the end of the last contract period to allow processing of large amounts of SSIES-3 data in a "production mode" has allowed larger amounts of data files of geophysical records to be produced from F16 and F17 in this contract period and placed on the in-house DMSP website for evaluation and use by UTD scientists.

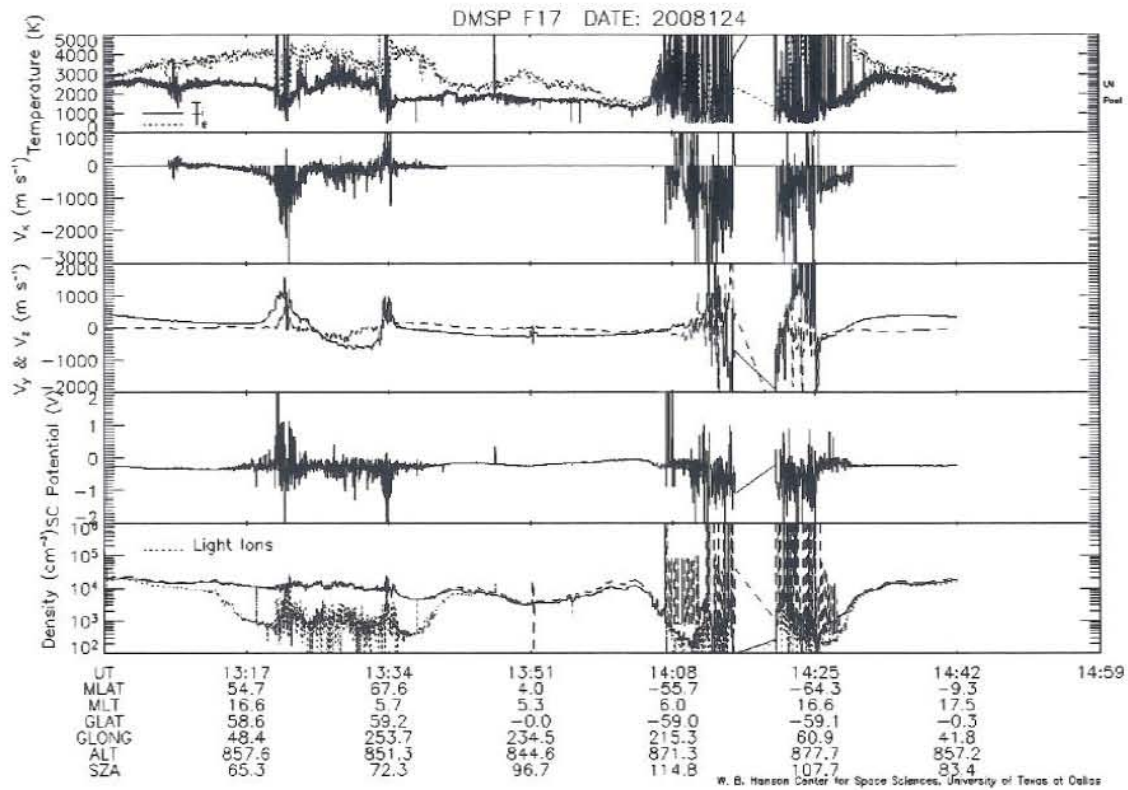
During this period AFRL requested that the current version of the UTD SSIES-3 data analysis software described above be delivered to AFRL in order that it could be implemented locally. We have made this delivery and will provide support as necessary to AFRL for the local implementation of this software.

A problem in the ion density measurements produced by the SM was identified at AFRL during the last contract period and it has now been determined that the plasma plates on



both F16 and F17 are undergoing much larger voltage excursions than anticipated and that this is affecting the SM. The plasma plates on board F16 and F17 were commanded into different voltage configurations to test the effects on the ion density measurements. It has been determined that the plasma plate was indeed the source of the problem and the plasma plate has been disabled on both spacecraft. It is possible that this issue will be revisited at a later point in the solar cycle when ambient conditions might be more favorable for proper plasma plate operation.

Figure 1 presents sample results using the current analysis software for data from the RPA, SM, electron sensor, and DM for one complete orbit of F17 on day 124 (May 3) of 2008. The top panel shows the electron temperature ( $T_e$ ) from the electron sensor as calculated by the on-board algorithm (dotted line). The solid line in this panel is the RPA-derived ion temperature ( $T_i$ ). These ion temperatures appear to be generally well-determined in most locations with a couple of exceptions. The first is in the northern hemisphere auroral zones (i.e.  $\sim 1320$  UT) where plasma conditions are rapidly varying on a spatial/temporal scale that precludes seeing a stable current-voltage curve over the one second period necessary for the RPA to make a complete measurement. The second area of problems is the southern hemisphere high-latitude region where there exist both regions of rapidly changing plasma conditions and regions of very low ( $< 5 \times 10^2 \text{ cm}^{-3}$ ) plasma density in which the RPA does not function well. The second panel contains the RPA determined ram ( $v_x$ ) component of the plasma drift. Note the extended period of zero drift in the middle of the orbit. This is a region of almost pure light ions (no  $\text{O}^+$ ). In such conditions the Levenberg-Marquardt algorithm is unable to differentiate between variations in the ram velocity and variations in the sensor potential with respect to the plasma. As such regions occur primarily at low latitude where the ram component of the ion velocity is generally very low we set  $v_x=0$  and solve for the value of the spacecraft potential. Otherwise, the determination of  $v_x$  shows quality problems in the same areas as  $T_i$ . The center panel shows horizontal cross-track (solid line,  $v_y$ ) and vertical (dashed line,  $v_z$ ) velocities measured by the DM. The northern high-latitude region shows the pattern of sunward convection in the auroral zones and anti-sunward convection over the polar caps indicative of a two-cell convection pattern commonly present during times of a southward interplanetary magnetic field. The DM also functions poorly during the low density conditions present in the southern hemisphere. The fourth panel shows the RPA calculated sensor potential relative to the plasma. The bottom panel gives the total ion density from the RPA (solid line), light ion ( $\text{H}^+$  plus  $\text{He}^+$ ) density (dotted line) from the RPA, and the total ion density from the SM (dashed line). The total ion density measurements are generally of good quality except in the active low-density southern hemisphere region. The reason for the apparent difference observed between RPA and SM derived density during the period of high light ion density is being investigated.



**Figure 1.** Summary plot of plasma parameters from the RPA, DM, electron sensor, and SM on DMSP F17. The top panel shows the ion temperature (solid line) and electron temperature (dotted line). The next panel shows the ram ion drift ( $v_x$ ). The center panel shows horizontal cross-track (solid line,  $v_y$ ) and vertical (dashed line,  $v_z$ ) velocities. The fourth panel gives the sensor potential. The bottom panel gives the ion density from the RPA (solid line), light ion ( $H^+$  plus  $He^+$ ) density (dotted line), and the ion density from the SM (dashed line).

#### 4. MISCELLANEOUS TASKS PERFORMED

During this period maintenance was performed on the DMSP data website, and work was begun to change the hosting of the DMSP data website to a computer controlled by the UTD Information Resources department in order to follow new UTD security policy. UTD has continued to provide support services to AFRL as requested during this period.

#### 5. WORK PLANNED FOR THE NEXT PERIOD

UTD will continue to develop and improve the F17 ground data analysis software and also to inspect and compare the results of the on-board algorithm with that of the ground software. Development will continue on the RPA processing software with improvements to the initial input parameters and refinement of the output feedback algorithm to identify and correct cases where the initial analysis has not functioned correctly. A quality flag algorithm similar to that used on SSIES-2 will be developed and implemented. We will improve the plasma plate software and begin the development of the electron sensor data processing software. We will work to identify and correct isolated cases of failure in the data processing software.

Studies of the dependence of ion drift on the sensor plane potential suggest that the orientation of the satellite conducting surfaces with respect to the sun may play a role. We will investigate this possibility with a view to improving the data quality in future generation of geophysical parameters.

The hosting of the DMSP data website will be changed to a computer controlled by the UTD Information Resources department in order to follow UTD security policy. We will continue to provide support to AFRL to help enable them to process F17 data.

#### **6. SCIENTISTS AND ENGINEERS CONTRIBUTING TO THIS RESEARCH**

W. R. Coley	Research Scientist
R. A. Heelis	Principal Investigator
M. D. Perdue	Research Engineer/Scientist
R. A. Power	Project Supervisor
P. C. Anderson	Research Scientist/Professor